Positioned For Speed
Positioned For Speed Global Network

Retül
Alphamantis Technologies
PowerTap
VELO Sports Center
Pro Tour Level Team Support

Team Sky
Garmin Sharp
Orica GreenEDGE
Team Europcar
Columbia Pro Cycling
Mtn Qhubeka
Pro Triathlete Support

Craig Alexander
Rachel Joyce
Tim Don
Leanda Cave
USAT Development
Objectives

1. Aerodynamics how and why?
2. How is it measured?
3. How to fit a rider with this information?
Speed Considerations

Power
Efficiency
Drag
Aerodynamics
Drag matters!

Speed and proportional energy demand by primary resistar
to forces during steady state (constant power) cycling

Proportion of energy output overcoming various resistance forces during steady state cycling
from flat road (gradient 0%) to very steep climbs (gradient 10%). Speed also shown for
various gradients while riding at 300 watts. The progression from air resistance being

Assumptions
Bike + rider: 75 kg
CdA: 0.300 m²
Crr: 0.005
(road tyres asphalt road)
Air density: 1.181
kg/m³
Drivetrain
Physiologic and physical correlates of level and uphill cycling performance.

University of Colorado, Applied Exercise Science Lab

Power vs. Drag

Uphill TT time: Power/weight

Level TT time: Power/A_D

Physiologic and physical correlates of level and uphill cycling performance.

University of Colorado, Applied Exercise Science Lab
Aerodynamic Drag Components

Drag force

- Size: $A_p$
- Shape: $C_D$
- Air density: $\rho$
- Velocity: $V^2$
What impacts aero drag force?

Major factors

• ↑ Air density ($\rho$) = ↑ drag
  • ↑ Temperature = ↓ $\rho$
  • ↑ Altitude = ↓ $\rho$
  • ↑ Barometric Pressure = ↑ $\rho$
  • ↑ Humidity = ↓ $\rho$

• Size of object
  • Effective Frontal Area (A) m$^2$

• Shape & roughness of object
  • Coefficient of Drag (Cd)

• Speed and type of air flow
  • turbulent & laminar

What can we influence?

- Generally not something we can influence, with exception of tracks (e.g. selecting track at altitude, climate controls)
- We can reduce Frontal Area by altering position of a rider and equipment changes
- We can reduce Cd by altering the shape of the rider and equipment and consider strategic roughness elements to impact on nature of the air flow
What impacts aero drag force?

Major factors

- **Air density** ($\rho$) = $\uparrow$ drag
  - **Temperature** = $\downarrow \rho$
  - **Altitude** = $\downarrow \rho$
  - **Barometric Pressure** = $\uparrow \rho$
  - **Humidity** = $\downarrow \rho$

- **Size of object**
  - Effective Frontal Area (A) m$^2$

- **Shape & roughness of object**
  - Coefficient of Drag (Cd)

- **Speed and type of air flow**
  - turbulent & laminar

What are we measuring?

- **Coefficient of Drag Area (CdA) m$^2$**
  - $\uparrow$ Coefficient of Drag (Cd)
  - $\downarrow$ Effective Frontal Area (A) m$^2$

- **Increase CdA =**
  - Slower for same power output
  - More power required to maintain same speed

- **Reduce CdA =**
  - Faster for same power output
  - Same speed for less power
• The rider accounts for ~70% of total aerodynamic drag.
• Hence rider positioning is the most important factor for seeking aero gains, but equipment choices are still significant.
Shape matters!

<table>
<thead>
<tr>
<th>Shape</th>
<th>Drag Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>sphere</td>
<td>0.47</td>
</tr>
<tr>
<td>half-sphere</td>
<td>0.42</td>
</tr>
<tr>
<td>cone</td>
<td>0.50</td>
</tr>
<tr>
<td>cube</td>
<td>1.05</td>
</tr>
<tr>
<td>angled cube</td>
<td>0.80</td>
</tr>
<tr>
<td>long cylinder</td>
<td>0.82</td>
</tr>
<tr>
<td>short cylinder</td>
<td>1.15</td>
</tr>
<tr>
<td>streamlined body</td>
<td>0.04</td>
</tr>
<tr>
<td>streamlined half-body</td>
<td>0.09</td>
</tr>
</tbody>
</table>

- These two objects pictured below provide the same amount of aero drag!
## Velocity

**TABLE 3. Correlations, 95% CI's, and P-values of drag area or projected frontal area vs. LTT finish time.**

<table>
<thead>
<tr>
<th>Variable X vs LTT Finish Time</th>
<th>r</th>
<th>95% CI around r</th>
<th>P-value (r &gt; 0.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTT Power</td>
<td>-0.589</td>
<td>(-0.184, -0.823)</td>
<td>&lt; 0.010</td>
</tr>
<tr>
<td>Ad</td>
<td>0.845</td>
<td>(0.634, 0.939)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Ap</td>
<td>0.468</td>
<td>(0.018, 0.761)</td>
<td>&lt; 0.050</td>
</tr>
<tr>
<td>Mass (rider)</td>
<td>0.091</td>
<td>(-0.379, 0.524)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>DuBois BSA</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Olds-93 Ap(%BSA)</td>
<td>0.018</td>
<td>(-0.440, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Olds-95 Ap(%BSA)</td>
<td>0.037</td>
<td>(-0.424, 0.483)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Heil-01 Ap(%BSA)</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Davies-80 Ap(%BSA)</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Pugh-74 Ap(%BSA)</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Olds-95 Ap</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Olds-95 Ap-Swain Corr Factor</td>
<td>0.036</td>
<td>(-0.425, 0.482)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Olds-95 Ap(BRS)</td>
<td>0.029</td>
<td>(-0.431, 0.477)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Heil-01 Ap</td>
<td>0.098</td>
<td>(-0.373, 0.529)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>McLean-93 Ap</td>
<td>0.010</td>
<td>(-0.446, 0.462)</td>
<td>&gt; 0.100</td>
</tr>
<tr>
<td>Heil-02 Ap(TAP)</td>
<td>0.099</td>
<td>(-0.372, 0.529)</td>
<td>&gt; 0.100</td>
</tr>
</tbody>
</table>
Drag Area

\[ A_p + C_D \]

CdA

Best Estimation of Drag Force
**Skin Friction & Form Drag**

- Skin friction due to boundary layer drag along object’s surface
- Form drag due to pressure gradient around object, air flow separation, wake turbulence
- For streamlined objects, skin friction is much greater than form drag
  - Minimal flow separation
- For bluff bodies, form drag is much greater than skin drag
- For cyclist in TT position:
  - Form drag ~93%
  - Skin friction ~7%

<table>
<thead>
<tr>
<th>Shape and flow</th>
<th>Form drag</th>
<th>Skin friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>~10%</td>
<td>~90%</td>
<td></td>
</tr>
<tr>
<td>~90%</td>
<td>~10%</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>
How texturing lowers drag

• Smooth Sphere
  • Fragile, laminar boundary layer
  • Early boundary layer separation
  • Large wake region
  • Higher drag for some speeds

Dimpled Sphere
  • Thicker, turbulent boundary layer
  • More robust boundary layer
  • Delayed boundary layer separation
  • Smaller wake region
  • Lower drag for some speeds
Measuring Aero Drag
How a Wind Tunnel Works

Air speed (mph)

Force (grams)
lateral
axial

Big Fan!

force-measuring fork mounts
How a Track System Works

Air speed (mph)

Force (grams)

- lateral
- axial

force-measuring fork mounts
How a Track System Works

Power = Force * Velocity

Air speed (mph)

Force (grams)

Power = Force * Velocity

V

power-measuring hub

crank arms

lateral

axial
How a Track System Works

Power = Force * Velocity

Wheel speed (mph)

Force (grams)
Power Meter Validation

Use power to measure drag

Power = Force * Velocity
Force = Power / Velocity

$F_{TOT} = F_a + F_r$

Validation of Testing Protocol

What we measure?

Drag force

- Size
- Shape
- Air density
- Velocity

\[ A_p \quad C_D \quad \rho \quad V^2 \]

CDA
Aero Testing Protocol

1. Physical assessment.
2. 3D Motion Capture to determine baseline (Retül).
3. Develop a position run list (Retül)
4. Develop an equipment run list
5. Run the positional tests (Alpha Mantis)
6. Run the equipment tests (Alpha Mantis).
7. Develop a list of recommendations for the rider and present a final report.
Positioning & Bike Set-up
Consideration: Proper Positioning (Fit)

Joint Angles
(mid range)

Alignments
(hips, knees, feet)

Movements
(technique)
Consideration: Proper Positioning (Fit)
Consideration: Proper Positioning (Fit)

Is Your Fit Unique?
Consideration: Proper Positioning (Fit)

Movement:  
- Ankling  
- Posture  
- Knee Tracking
Consideration: Proper Positioning (Fit)

Athlete Considerations:
- Limitations
- Individuality
- Goals
- Desires
Adaptation / Sustainability

Stability
Duration
Adaptation / Sustainability: Reach
Adaptation / Sustainability: Saddle
Adaptation / Sustainability: Arm Pads
Adaptation / Sustainability: Bar Angulation
Adaptation / Sustainability: Extensions

Relaxed

Torque/Tension
Generating Confidence

- Establish a solid baseline:
  - 3x20 Rule: 3 runs of 20 laps with +/- 1%
  - Look for sources of inconsistency:
    - Riding position
    - Equipment (brakes rubbing, etc...)
  - Range of CdA should be “right-sized”
    - Fast TT ~ 0.230 m^2
    - Fast Road ~ 0.290 m^2
    - Fast Track Endurance ~ 0.190 m^2
Generating Confidence

- Return to baseline:
  - When a result looks puzzling, too good to be true, or terrible.
  - At least once per test session.
Generating Confidence

- Use A-B-A protocol for change-on-the-fly:
  - Useful for testing posture (shrug)
What’s the speed impact?

- Aero rule of thumb
  - 0.01m² change in CdA ~= 1 second per km
    - Mostly flat terrain
    - With a CdA of 0.28m², 0.01m² = 3.6%
  - It may be a bit more or less depending on the actual CdA and speed of the athlete
  - Consider this when setting expectations for improvement
## 40K Time Savings

<table>
<thead>
<tr>
<th>300 watts</th>
<th>Standard</th>
<th>Optimized</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>58:29</td>
<td>56:40</td>
<td>1:49</td>
</tr>
<tr>
<td>Helmet</td>
<td>58:29</td>
<td>57:51</td>
<td>:40</td>
</tr>
<tr>
<td>Wheels</td>
<td>58:29</td>
<td>57:39 (57:26)</td>
<td>:50 (1:03)</td>
</tr>
<tr>
<td>Fork</td>
<td>58:29</td>
<td>58:01</td>
<td>:28</td>
</tr>
<tr>
<td>Position + Eq</td>
<td>58:29</td>
<td>51:53</td>
<td>6:36</td>
</tr>
</tbody>
</table>

**Art & Science of Triathlon**

*2014 International Coaching Symposium*

*USA Triathlon*
Clean Up Your Bike....

https://www.youtube.com/watch?v=Rli9JyhHs
Summary

• Wind tunnels and Track Aero System use the same principles
• Aero: How efficiently you convert power into speed
• You have direct influence over key aero factors of
  • Frontal area
  • Coefficient of Drag
  • By making bike position and equipment choices
    • Textures and dimples can sometimes help lower drag
• When drag numbers conflict with comfort
  – Give time to adapt
  – Pick comfort